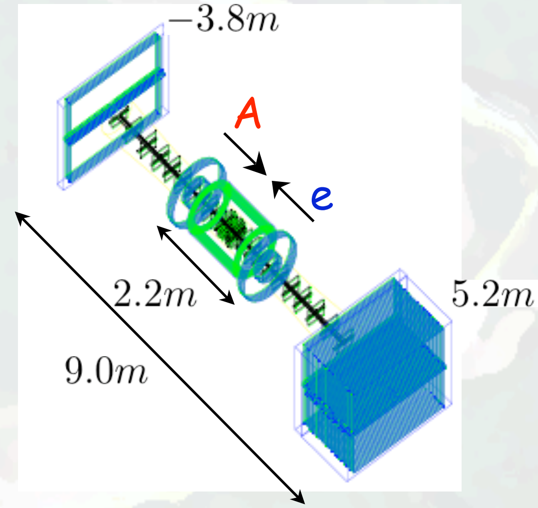
eRHIC Detector Design Studies - Implications and Constrains on the Accelerator/Detector interface

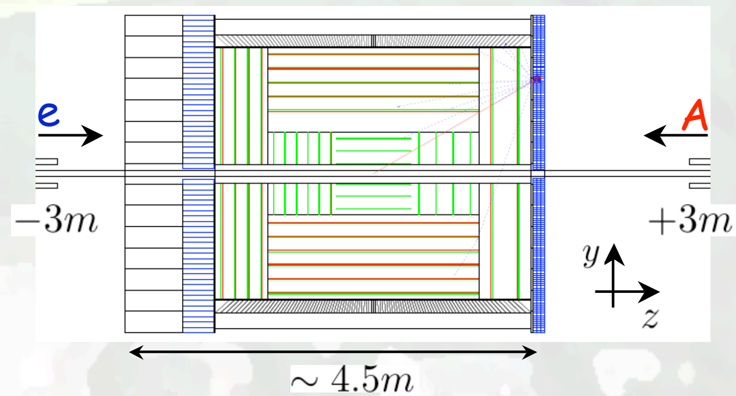
Bernd Surrow

Massachusetts Institute of Technology

Outline

- Physics program driven requirements
  - Constraints imposed by collider kinematics
    - eRHIC - Detector design aspects
      - General considerations
      - Design 1: Forward physics (unpolarized eA MPI-Munich group)
      - Design 2: General purpose (unpolarized/polarized ELECTRon-A)





  - Constraints on accelerator/detector interface and background issues
- Summary and Outlook

Physics program driven requirements

General considerations: Machine aspects

- Beam species and energy
  - Polarized (transverse/longitudinal up to 70%) electron (5-10GeV)/positron (10GeV)
  - Polarized (transverse/longitudinal up to 70%) protons (50-250GeV) and potentially polarized ^{3}He
  - Light and heavy nuclei (e.g. Au) 100GeV/u

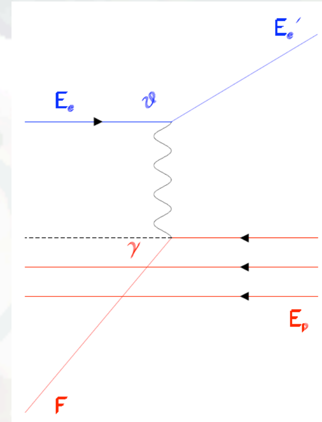
Variable centre-of-mass energy: 30-100GeV

- Luminosity
  - 10GeV electron/positron storage ring: ep (~10^{33}cm^{-2}s^{-1}) (10GeV on 250GeV) and eA (~10^{31}cm^{-2}s^{-1}) 10GeV on 100 GeV/u): Bunch crossing frequency: 28MHz Constrain on choice of detector/trigger system!
  - Energy recovery superconducting linac (ERL): ep (~10^{34}cm^{-2}s^{-1}) and eA (~10^{32}cm^{-2}s^{-1})
- Polarization: Transverse/longitudinal up to 70% for e/p
  - Spin rotator system
  - Polarization measurement (e/p)
  - Local polarimetry (Track trans./long. spin manipulation around IR)
  - Relative luminosity measurement
- Machine background
  - Synchrotron radiation (System of absorbers and collimators - Constrain on beam pipe design)
  - Beam-gas background (Electron/positron and proton beam - Detector shielding arrangement)

Physics program driven requirements

General considerations: Detector aspects

- Measure precisely scattered electron over large polar angle region (Kinematics of DIS reaction)
- Tag electrons under small angles (Study of transition region: DIS and photoproduction)
- Measure hadronic final state (Kinematics, jet studies, flavor tagging, fragmentation studies, particle ID)
- Missing E_T for events with neutrinos in the final state (W decays) and Physics beyond the SM (Hermetic detector)



- Zero-degree photon detector: Control radiative corrections and luminosity measurement (ep Bremsstrahlung)
- Tagging of forward particles (Diffraction and nuclear fragments) such as...:
  - Proton remnant tagger
  - Zero degree neutron detector

Constrain on machine layout!

- Challenge to incorporate above in one detector: Focus on two specific detector concepts!

Constraints imposed by collider kinematics

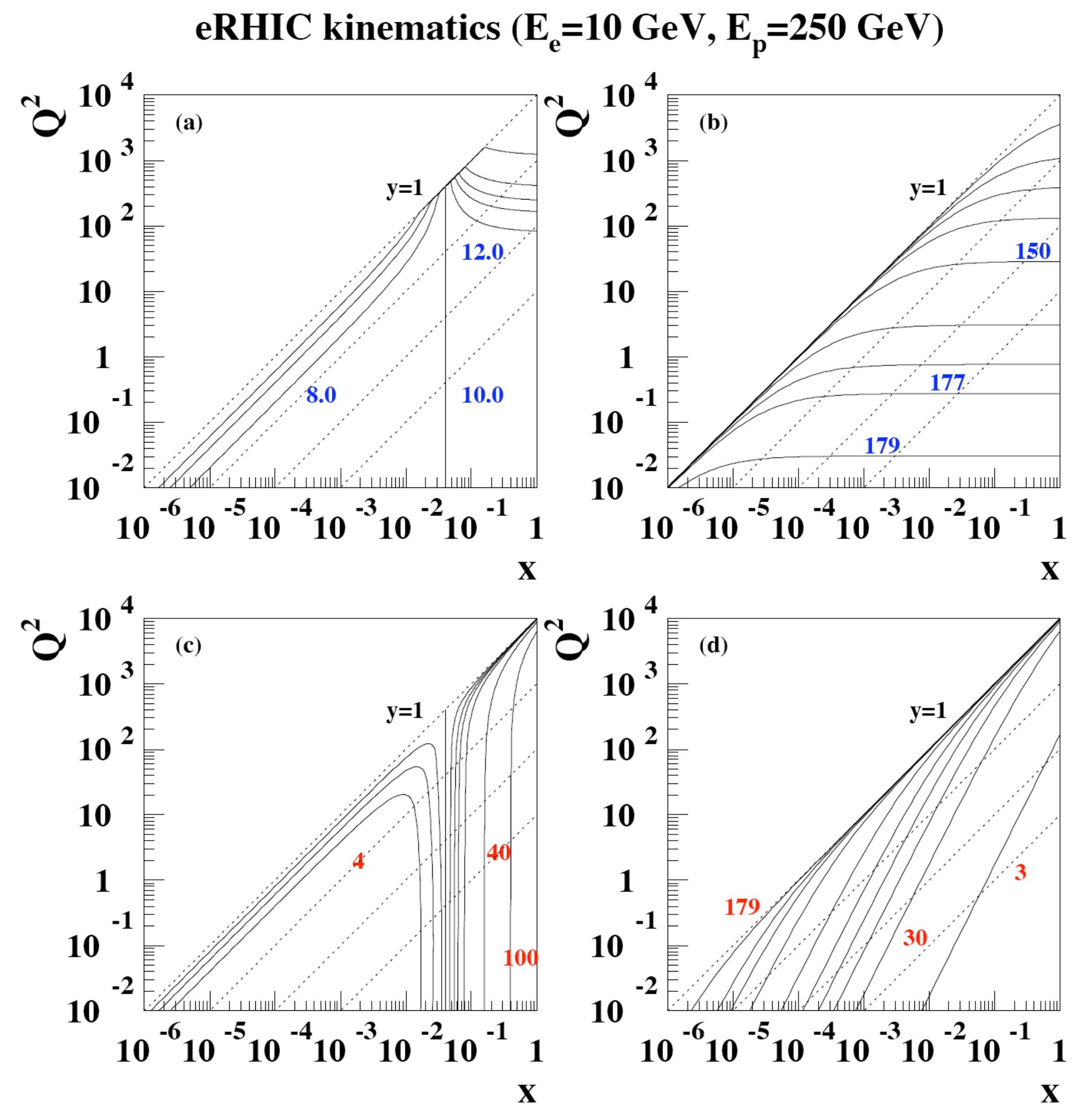
- General considerations

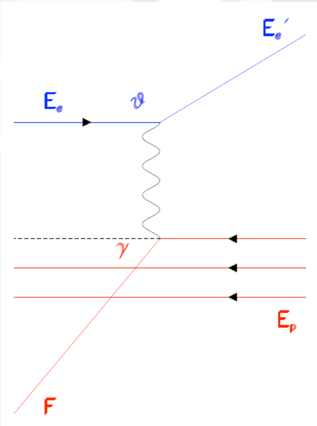
Lines of constant electron energy (E'_e)

Lines of constant electron angle (ϑ'_e)

Lines of constant hadron energy (F)

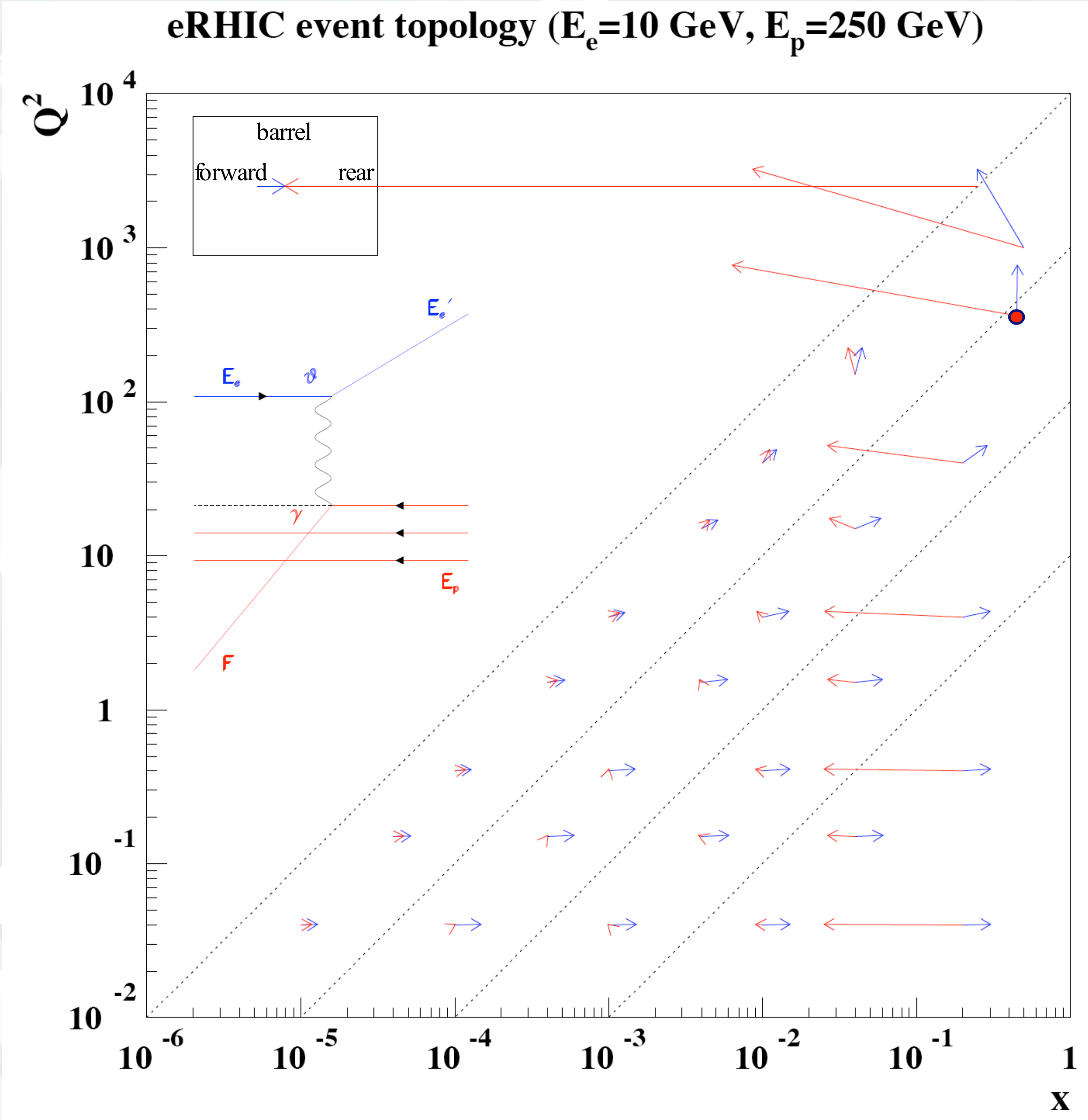
Lines of constant hadron angle (γ)





Constraints imposed by collider kinematics

- Event topology



- High-x-high Q^2: Electron predominantly in barrel/forward direction (High energy) and current jet in forward direction (High energy)

- Low-x-low Q^2: Electron and current jet (low energy) predominantly in rear direction

- High-x-low Q^2: Electron in rear and current jet (High energy) in forward direction

$Q^2 = 361 GeV^2 \quad x = 0.45$

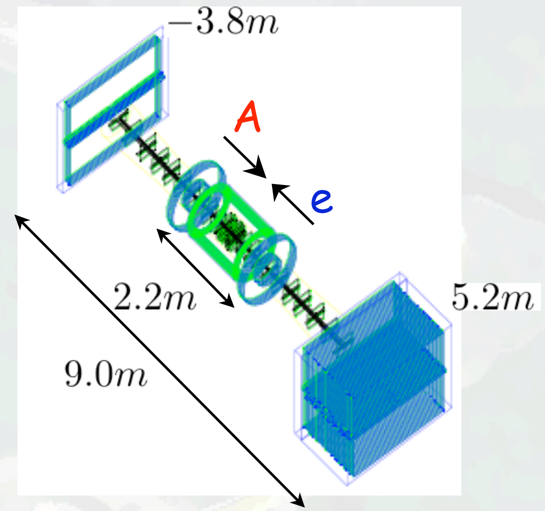
$E_e' = 18 GeV \quad F = 104 GeV$

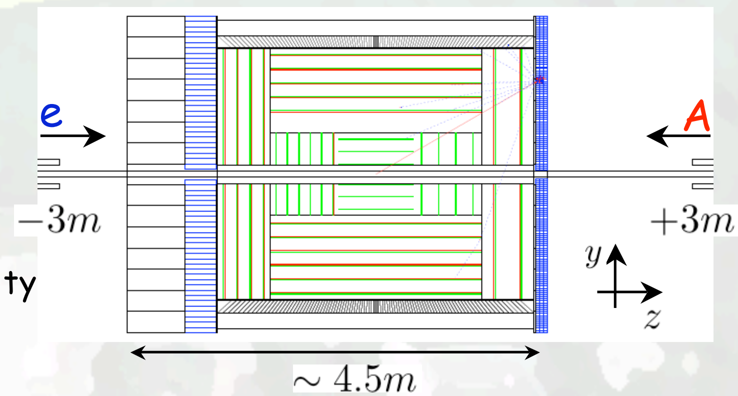
$\vartheta_e' = 90° \quad \vartheta_h = 10°$

eRHIC - Detector design aspects

General considerations

- Design 1: Forward physics (unpolarized eA MPI Munich group):
  - Specialized detector system to enhance forward acceptance of scattered electrons and hadronic final state
  - Main concept: Long inner dipole field (7m)
  - Required machine element-free region: approx. ±5m
- Design 2: General purpose (unpolarized/polarized ELECTRon-A):
  - Compact central detector (Solenoidal magnetic field) with specialized forward/rear tagging detectors/spectrometers to extend central detector acceptance
  - Required machine element-free region: approx. ±3m
- Detector sub-systems in both design concepts:
  - Zero-degree photon detector (Control radiative corrections and luminosity measurement)
  - Tagging of forward particles (Diffraction and nuclear fragments) such as...:
    - Proton remnant tagger
    - Zer0-degree neutron detector

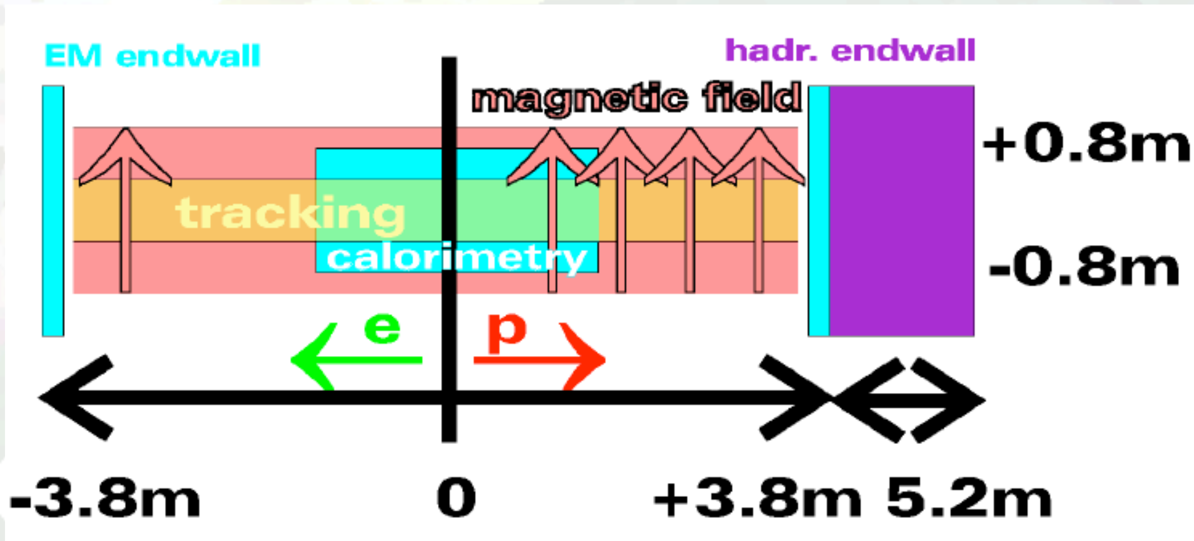




eRHIC - Detector design aspects

I. Abt,
A. Caldwell,
X. Liu,
J. Sutiak,
MPP-2004-90, hep-ex 0407053

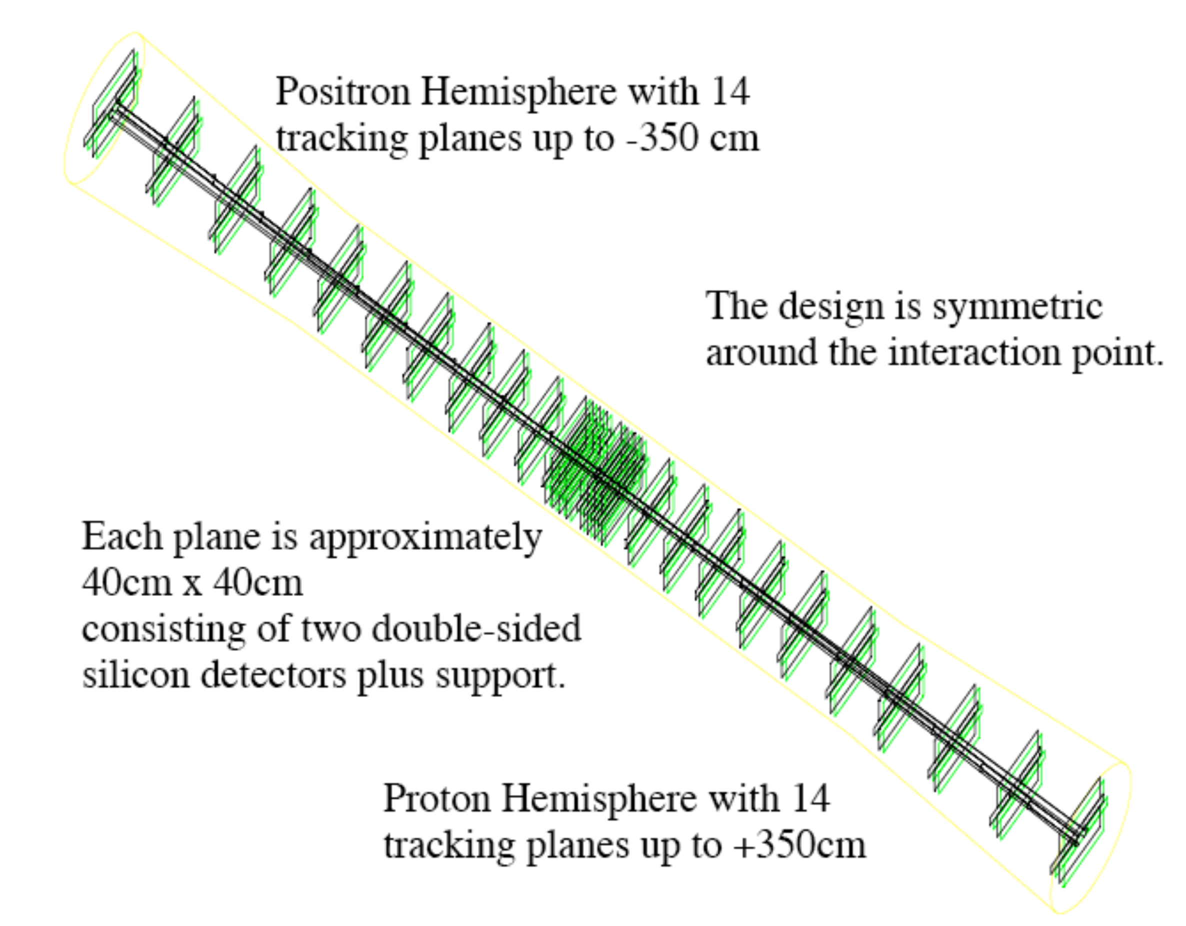
- Design 1: Forward physics (unpolarized eA MPI-Munich group) (1)
  - Detector concept
    - Compact detector with tracking and central EM calorimetry inside a magnetic dipole field and calorimetric end-walls outside:
      - Bend forward charged particles into detector volume
      - Extend rapidity compared to existing detectors
    - Tracking focuses on forward and backward tracks
    - No tracking in central region



eRHIC - Detector design aspects

I. Abt,
A. Caldwell,
X. Liu,
J. Sutiak,
MPP-2004-90, hep-ex 0407053

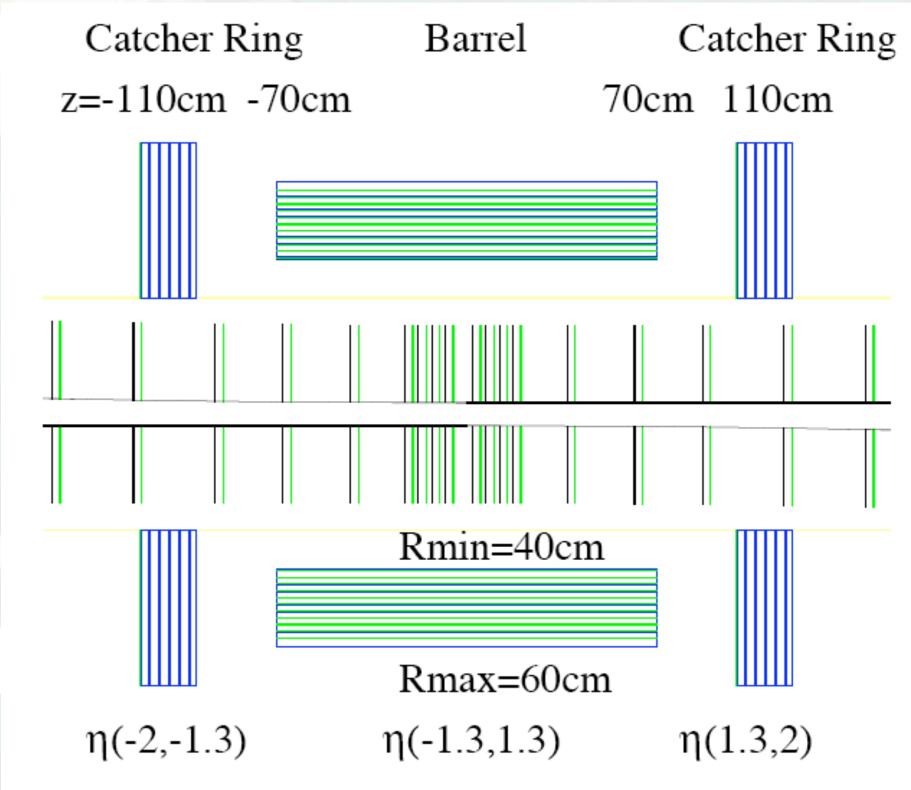
- Design 1: Forward physics (unpolarized eA MPI-Munich group) (2)
  - Tracking system:
    - High-precision tracking with $\Delta p_T/p_T \sim 2\%$
    - Angular coverage down to $\eta \approx 6$ over the full energy range
    - Concept: 14 Si-strip tracking stations (40 X 40 cm)
    - Assumed hit resolution: 20μm
    - Momentum resolution from simulations: Few percent!

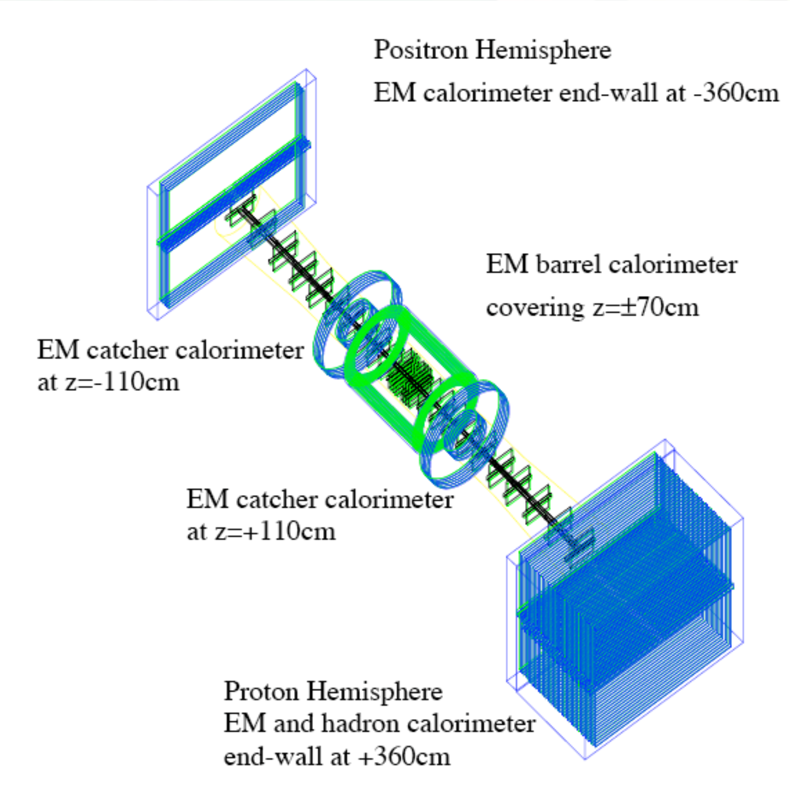


eRHIC - Detector design aspects

I. Abt,
A. Caldwell,
X. Liu,
J. Sutiak,
MPP-2004-90, hep-ex 0407053

- Design 1: Forward physics (unpolarized eA MPI-Munich group) (3)
  - Calorimeter system:
    - Compact EM calorimeter systems: Si-Tungsten
    - Forward hadron calorimeter: Design follows existing ZEUS calorimeter

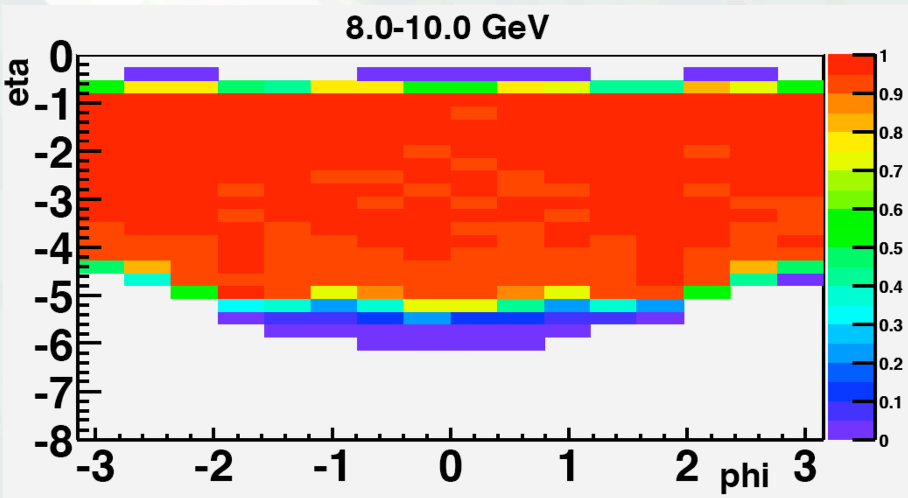


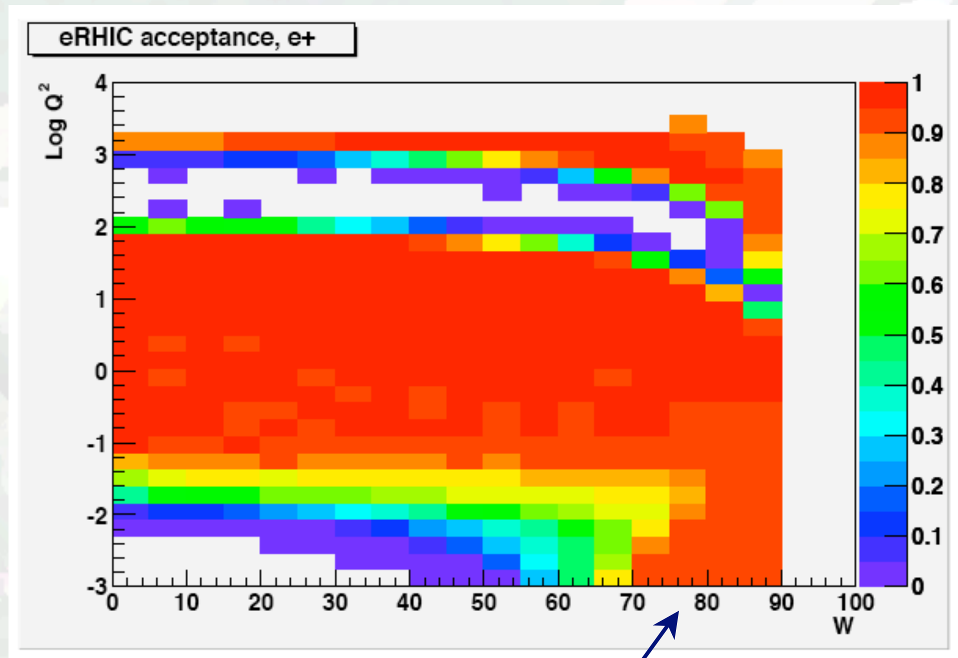


eRHIC - Detector design aspects

I. Abt,
A. Caldwell,
X. Liu,
J. Sutiak,
MPP-2004-90, hep-ex 0407053

- Design 1: Forward physics (unpolarized eA MPI-Munich group) (4)
  - Acceptance:
    - Full tracking acceptance for $|\eta| > 0.75$ - No acceptance in central region $|\eta| < 0.5$
    - Q^2 acceptance down to $0.05\,\mathrm{GeV}^2$ (Full W range) - Full acceptance down $Q^2 = 0\,\mathrm{GeV}^2$ for W>80GeV
    - High x: Electron (Q^2) and Jet (x) to determine event kinematics





Track efficiency:

- Full efficiency below 6GeV for $\eta < -8$
- For larger energies, full efficiency for $\eta < -5$

$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right)$$

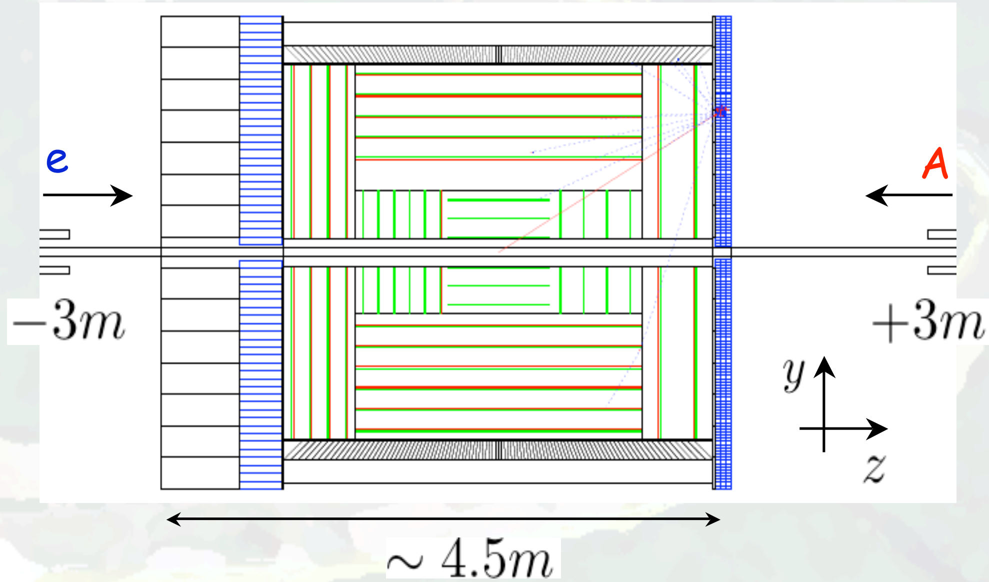
$$W^2 \approx \frac{Q^2}{x}$$

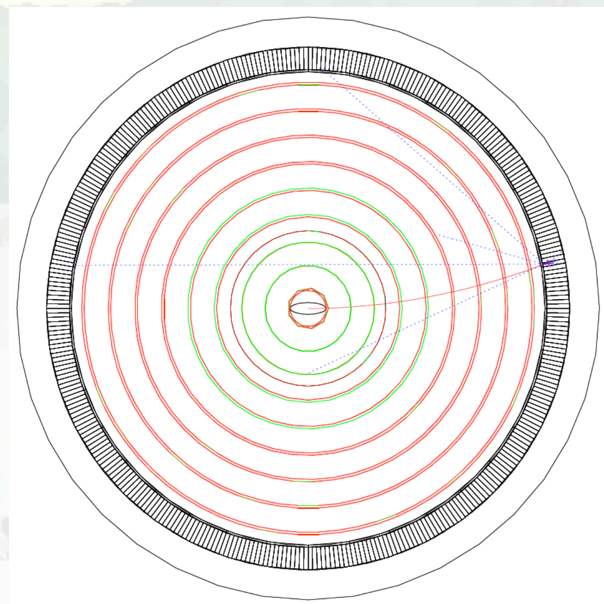
eRHIC - Detector design aspects

J. Pasukonis,
B.S.

- Design 2: General purpose (unpolarized/polarized ELECTRon-A) (1)

  - Detector concept:
    - Hermetic detector system inside ±3m machine element free region
    - Starting point:
      - Barrel and rear EM system: e.g. Si-Tungsten (Similar to Design 1)
      - Forward EM/hadron calorimeter: e.g. Pb-scintillator
      - Tracking system and barrel EM inside solenoidal magnetic field
      - Tracking system based on high-precision Si (inner) and micro-pattern technology (Triple-GEM) (outer)





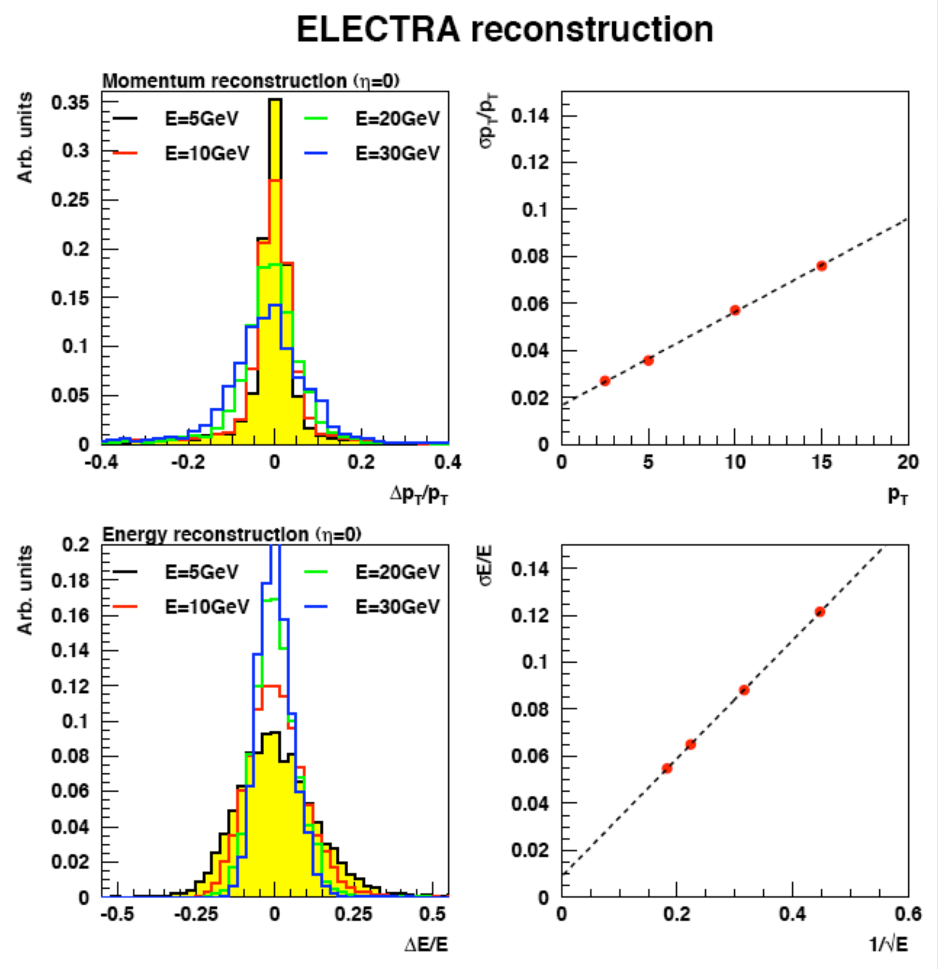
eRHIC - Detector design aspects

J. Pasukonis, B.S.

Design 2: General purpose (unpolarized/polarized ELECTRon-A) (2)

- ELECTRA detector simulation and reconstruction framework:
  - GEANT simulation of the central detector part (tracking/calorimetry) available: Starting point
  - Calorimeter cluster and track reconstruction implemented
  - Code available through CVS repository:

    http://starmac.lns.mit.edu/~erhic/electra/
  - To-do-list:
    - Evaluate and optimize detector configuration
    - Design of forward tagging system and needed particle ID systems for various exclusive processes
    - In particular for eA events: Optimize forward detector system for high-multiplicity environment

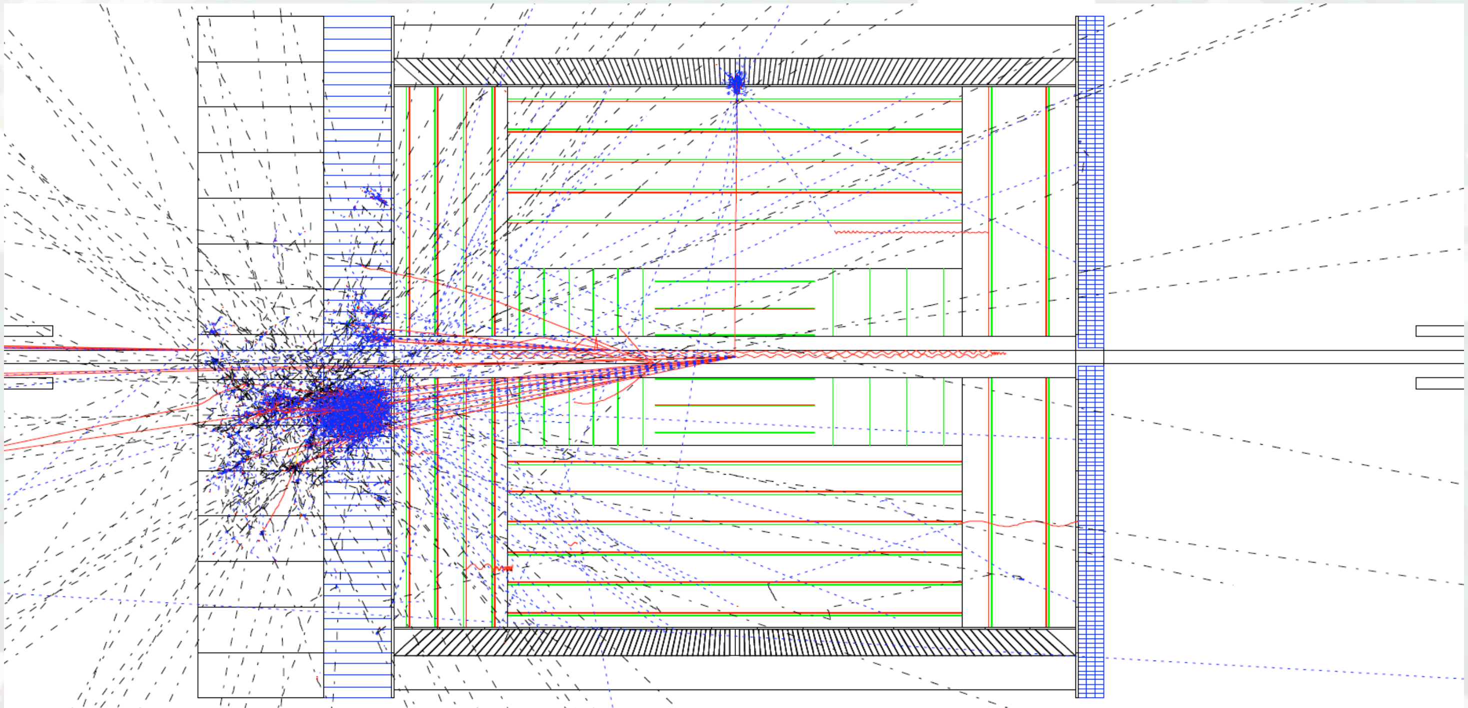


eRHIC - Detector design aspects

J. Pasukonis, B.S.

- Design 2: General purpose (unpolarized/polarized ELECTRon-A) (3)
  - Simulated ep DIS event (LEPTO)

Lower Q^2 acceptance ≈ 0.1GeV2



Side view $Q^2 = 361 GeV^2 \quad x = 0.45 \quad E_e = 18 GeV$

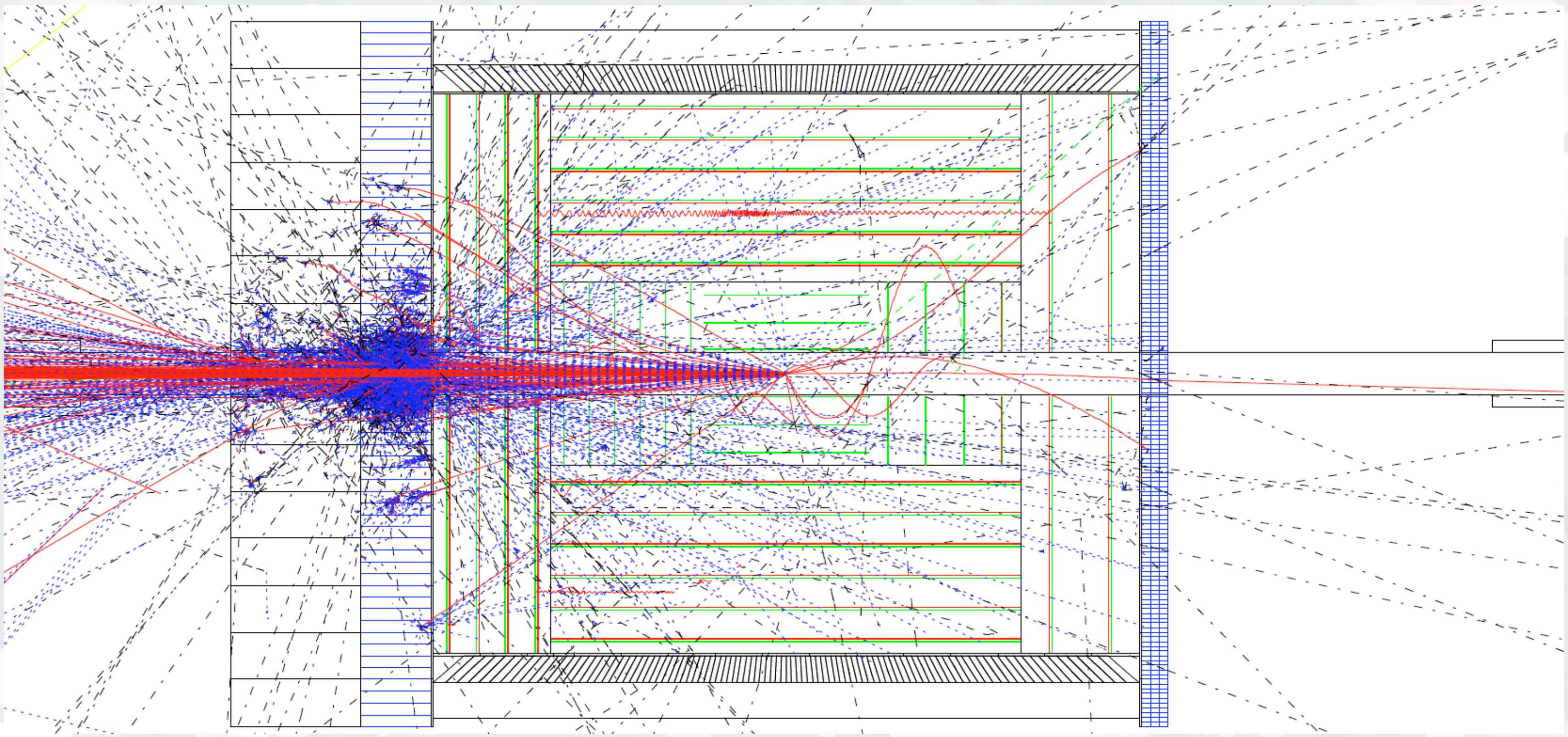
DIS generators used so far:

- LEPTO
- DJANGO

eRHIC - Detector design aspects

J. Pasukonis,
B.S.

- Design 2: General purpose (unpolarized/polarized ELECTRon-A) (4)
  - Simulated eCa event (VNI)



Top view

Interaction region and background issues

- IR region
  - Design 1: Forward physics (unpolarized eA MPI-Munich group)
    - Machine element free-region: approx. ±5m
    - Physics program could be accomplished at lower ("initial") luminosity operation
  - Design 2: General purpose (unpolarized/polarized ELECTRon-A)
    - Machine element free-region: approx. ±3m
    - Physics program requires high luminosity operation
- Synchrotron radiation background
  - Optimize beam pipe shape
    - Accommodate synchrotron radiation fan generated by e-beam as a result of beam separation (C. Montag's talk)
    - Maximize detector acceptance
  - Design of absorber (Protection of septum and minimize backscattered synchrotron radiation) and masking system: Initial studies based on a GEANT simulation of a V-shaped absorber presented by J.Beebe-Wang et al. at PAC2005
- Beam-gas background
  - Bremsstrahlung of electrons with residual gas (off-momentum electrons) and proton-beam gas background
    - Shielding and collimation
    - Minimize dead-material close to the beam
    - Good vacuum conditions crucial

Summary and Outlook

- **Detector design issues**
  - Well-developed design of a Forward detector system focusing on low-x / high-x physics (Adaptation and optimization of a detector presented for the HERA III program)
  - Design of a compact central detector started: Detector simulation and reconstruction framework: ELECTRA (CVS repository http://starmac.lns.mit.edu/~erhic/electra/)
  - Possible scenarios of both design concepts:
    - 1 detector only (Staging): Start program with Forward physics detector system followed by an upgrade of the interaction region and installation of a central detector system re-using parts of the Forward detector system (e.g. rear and forward calorimeter)
    - 2 IR regions would allow to accommodate both detector concepts independently

- **Constraints and implications of machine/detector interface**
  - Inner-most machine elements
  - Synchrotron radiation and other machine related background
  - Incorporate forward and rear tagging system including luminosity monitoring system into machine layout